*TITLE OF INVENTION*

# Revolutionary barrier for rockfall or the like: Maintenance-free, highly efficient in dissipating kinetic energy, and fast in installation

(Inventor: Yucheng Pan; email: pany@hawaii.edu)

## *CROSS-REFERENCE TO RELATED APPLICATIONS*

**U.S. Patent Documents**

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| 4819915 | Apr., 1989 | Cargnel | 256/12.5. |
| 5186438 | Feb., 1993 | Cross and Smith | 256/13.1. |
| 5299781 | Apr., 1994 | Barrett Hearn and McMullen | 256/12.5. |
| 5535861 | Jul., 1996 | Young | 188/280. |
| 5961099 | Oct., 1999 | Thommen Jr. | 256/12.5. |
| 6027785 | Feb., 2000 | Yoshida | 428/131 |
| 6131873 | Oct., 2000 | Blazon and Bookwater | 248/548. |
| 6592103 B2 | Jul., 2003 | Sennhauser | 256/12.5. |

**Foreign Patent Documents**

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| JP9310313 | Dec., 1997 | Kenkichi | E01F7/04 |
| EP0877122 | Nov., 1998 | Laurent | E01F7/04 |
| JP2001064917 | Mar., 2001 | Katsuo | E01F7/04 |
| JP2002302911 | Oct., 2002 | Sakae, Mitsuyoshi, Kazufumi | E01F7/04 |
| JP2002047617 | Feb., 2002 | Eiichi | E01F7/04 |

## *BACKGROUND OF THE INVENTION*

1. Field of the Invention

The present invention relates to a safety net system for restraining rock falls or the like and to devices like cable braking systems for absorbing high impact energy in a rockfall net or the like.

2. Description of the Related Art

A plethora of safety nets or impact fences have been devised to absorb kinetic energy upon impact, like US Pat. No. 6,592,103 B2 Sennhauser; US Pat. No. 5,961,099 Thommen Jr.; US Pat. No. 4,730,810 Rambaud; US Pat. No. 5,186,438 Cross and Smith; JP Pat. No. 2002047617 Eiichi; JP Pat. No. 2001064917 Katsuo; JP Pat. No. 2002302911 Sakae, Mitsuyoshi, Kazufumi; and EP Pat. No. 0,877,122 Laurent. These safety nets or impact fences are installed in an upright position together with upright supporting posts, generally closely spaced, with wire mesh, cable nets, or ring nets attached to the top and bottom of the posts, usually through top and bottom supporting cables. These safety nets or impact fences have serious weaknesses as described below, with brief comparison with my current invention, the Pan-barrier.

Segmentation. The numerous upright posts segment the conventional nets or fences into segments, each confined within two adjacent posts. In case of an impact, the impact energy is mainly focused on one segment, greatly reducing the capability of the system as a whole. It is well known that putting the nets down slope side of the posts is more effective than putting them upslope side of the posts because of segmentation: the posts segment the nets more effectively for the upslope configuration during an impact. The nets behave as springs during impact, with their spring force F proportional to their amount of extension x, namely $F = kx$. Without segmentation, the amount of extension x provided by the whole system of cables and nets is large, providing a large force F and a large stopping distance; with segmentation, the amount of extension x provided by one segment of cables and nets is small, providing a small force F and a short stopping distance. The ideal barrier would be segmentation-free or post-free, which is my current invention–the Pan-barrier.

Short stopping distance. Because both the top and bottom of the conventional nets or fences are attached to the upright posts, impact objects need to be stopped within a short distance created by the bulging of the nets or fences during impacts. Short stopping distance results in great deceleration of impact objects, which in turn results in great impact force on the nets or fences. The Pan-barrier, on the other hand, provides exceedingly large stopping distance through effective configurations.

Full load of impacts. The conventional nets or fences take the full load of impacts because they themselves stop the impact objects completely, with gravity working against them. The Pan-barrier, on the other hand, diverts impacts to the ground with gravity working for it–not against it–during impact.

Embedding and sagging. The conventional nets or fences stop impact objects by means of bulging at the point of impact; consequently the impact objects very likely embed in the bulge, creating unsightly sight, reducing the effectiveness and height of the nets or fences, and requiring maintenance or even destruction of the nets. The Pan-barrier, on the other hand, does not have embedding and sagging problems due to its configurations.

Accumulation of debris. With time, accumulation of debris in front of (upslope) the conventional nets or fences not only reduces their effective height but also provides jumping ramps for following rockfall or the like. The Pan-barrier, on the other hand, does not have debris accumulation problem and actually benefits from it.

Material cost for conventional nets and fences is high as they are designed to take the full load of impacts. As the impact energy level goes up, the cost of materials goes up quickly. The material cost for the Pan-barrier, on the other hand, is much lower as it is designed to dissipate only a small fraction of the impact energy in exceedingly large stopping distances.

Labor cost for installation and maintenance is a major cost for conventional rockfall nets and fences. Installing posts, usually many, their tiebacks, and attaching cables and nets onto the posts are a major part of the installation. Maintenance to keep the fences in proper working condition requires access to the fences and cleaning out objects embedded in and accumulated in front of the fences. Often it is necessary to dismantle the fences in order to do the cleaning out after each major impact, together

with replacement of braking devices. The cost of installation and maintenance of the Pan-barrier, which is maintenance-free and almost post-free (only requires two or three posts), is greatly reduced.

Nets or fences with flexible posts, like US Pat. No. 5,299,781 Barrett, Hearn, and McMullen, and US Pat. No. 4,819,915 Cargnel, share the same problems of segmentation, short stopping distance, full load of impact, embedding and sagging, debris accumulation, high material cost, and high installation and maintenance cost. While diverting some impact load to the ground, nets or fences with flexible posts create a large load for themselves: centrifugal force. By confining the impact objects to a circular motion with the posts as the rigid radius, the nets or fences have an additional centrifugal force to counter: $F= mv^2/r$. As the speed v of the impact objects is generally large, magnified by the square power, and the post length r generally small, this additional centrifugal force F created by flexible posts is generally very large.

Many devices or mechanisms, like cable brakes, have been invented to increase the stretching or giving capability of the nets or fences upon impacts, like US Pat. No. 6,131,873 Blazon and Bookwater; US Pat. No. 6,027,785 Yoshida; US Pat. No. 5,535,861 Young; and JP Pat. No. 9,310,313 Kenkichi. These braking or stretching devises or mechanisms, however, cannot be used repeatedly and need to be replaced after each major impact. My current invention, the weight braking system, on the other hand, can be used repeatedly without limits or loss of effectiveness and without replacement or maintenance. Unlike the conventional cable brakes which loosen the cable after each engagement, the weight braking system actually tightens the cable after each engagement.

***BRIEF SUMMARY OF THE INVENTION***

A new safety net system called Pan-barrier is invented to stop rockfall, landslides, debris flows, snow avalanches, or the like, with three striking advantages: completely maintenance-free, highly efficient in dissipating and diverting kinetic energy, and very fast in installation. The Pan-barrier, which uses a new type of cable braking system–the weight braking system–that can be used or activated repeatedly without limits or maintenance, is greatly cheaper and greatly better than currently available rockfall or the like barriers or safety nets. The Pan-barrier consists of the following components: 1) one frame or peripheral cable or wire rope with its two ends attached together by wire rope clips or the like to form a rectangular shape or the like; 2) one or two layers of flexible mesh (chain link, double-twisted or the like) and one optional layer of cable nets or ring nets attached (sewed) onto the frame cable, forming the Pan-barrier sheet; 3) two or possibly more ground anchors holding one side of the frame cable on or close to the ground; and 4) two or possibly more supporting cables (tiebacks), each tied to a ground anchor, erected by a post, and equipped with the weight braking system, holding the opposite side of the frame cable at a designed height. The Pan-barrier sheet is installed oblique to the ground or slope, forming a wedge space between the sheet and the ground, with the opening facing upslope where rock falls or the like come from. Impacts occur inside the wedge, on the ground facing or under side of the Pan-barrier sheet.

## *DETAILED DESCRIPTION OF THE INVENTION*

Figure 1 shows a schematic view of the Pan-barrier system. The Pan-barrier consists one looped frame or peripheral cable with mesh panels and optional cable or ring net panels sewed to it, forming the Pan-barrier sheet; two anchors (three or more if the ground is not leveled) to hold one side of the sheet on the ground; and two tiebacks (three if the ground is not leveled), each with its own anchor, post and weights, hold the opposite side of the sheet to a designed height. The Pan-barrier sheet is installed oblique to the ground or slope (not upright). The smaller the angle between the Pan-barrier sheet and the ground, the more efficient the Pan-barrier system.

Figure 2 shows a schematic top view of the Pan-barrier system.

Figure 3 shows a schematic cross section view of the Pan-barrier system and a new weight tensioning and braking system. The weight braking system is created by attaching weights (e.g., metals, concretes, boulders, logs) to the tieback cable on the opposite side of the post from the Pan-barrier sheet. The weights create sagging in the tieback cable. The benefits of the attached weights are four-fold. First the weights keep the system tensioned to avoid and eliminate any sagging of the Pan-barrier sheet before impacts. Secondly, in response to impacts, the gravity and upwards or vertical acceleration of the weights keep the tieback cable tensioned while the cable stretches by eliminating its sagging. Thirdly, the forward or horizontal movement of the weights with the tieback cable reduces the speed of impact objects. Lastly, the gravity and downward acceleration of the weights after impacts help to tension and eliminate embedding, if any, of the Pan-barrier sheet. Multiple weights are attached to the tieback cable to allow sequential activation of the weight braking system. For example, a weight that is fixed on the tieback cable (not hung from a string) will be activated fully and immediately after impact while a weight hung from a string to the tieback cable will be activated a split second later due to the horizontal component of movement of the tieback cable (a real life analogy: if you are holding a weight through a long string and you start to move horizontally, the weight hardly moves at the beginning). The longer the strings, the later the activation. Similarly, multiple weights laid on the ground and connected to the tieback cable using different lengths

of strings can also serve the purpose of sequential activation of the weight braking system.

Large Pan-barrier is beneficial in stopping rock falls or the like. If the mass of a Pan-barrier system, $m_p$ (including weights for braking and tensioning), is as large as that of an impact boulder, $m_b$, then the mass of the Pan-barrier itself, without any help from anchors, reduces the speed of the impact boulder by half according to momentum conservation, $m_b*v = (m_b + m_p)* 0.5v$. Or put it simply, you do not need to exert much force when you use a heavy object to stop a light one. On the other hand, to use a light object to stop a heavy one is very difficult.

The connection between the frame cable and the anchors that hold the frame cable to the ground is through rings so that movement or sliding is allowed. The connection between the frame cable and the tiebacks is through thimbles or the like that allows sliding. To prevent the tiebacks from sliding into the sheet therefore making the top side of the frame cable shorter, a stopper like a U bolt is fixed on the frame cable (Fig 2). During impacts the tiebacks tend to slide to the outside (making the top side of the frame cable longer). The connection between the tieback cables and the posts is through pulleys or the like that allows easy sliding. A safety device is added to keep the tieback cables from detaching from the pulleys. Due to the easy lateral movement of the tieback cables, the connection between the frame cable and the two end tieback cables, however, can be fixed (no sliding).

The Pan-barrier system is not segmented. The Pan-barrier sheet is one sheet supported by one frame cable. As a result, the Pan-barrier system is extremely capable of giving or stretching in response to impacts. For example, for a 400-ft (length) Pan-barrier sheet with impacts occurred in the middle, the giving distance would be a whopping 20 ft if the frame cable and the mesh panels, which are large, could be stretched by 2 feet, namely $[(400+2)/2]^2 = (400/2)^2 + 20^2$. In addition, the tieback cables, which are usually quite long and are connected directly to the frame cable, further extend the dimension of the Pan-barrier system as a whole. With the exceptionally large stretching capability of the tieback cables due to the weight braking system, the giving distance of the Pan-barrier system as a whole upon impacts is tremendous. This extremely large giving distance extends impact time, which in turn results in small impact force, as impact force $F \doteq mv/t$, where m is the mass of

impact objects, v the speed of impact objects before impact, and t the impact time after which the impact objects completely stop. For example, if m = 20 tons, v = 50 ft/s, for an impact giving distance of 0.1 foot like between a boulder and a concrete wall (corresponding to an impact time of 0.004 second), the average impact force F is 7777 tons; if the impact giving distance is increased to 30 feet like between a boulder and a Pan-barrier (corresponding to an impact time of 1.2 seconds), the average impact force F is only 26 tons.

The most efficient feature of the Pan-barrier system in reducing impact force is the small angle between the Pan-barrier sheet and the ground. This oblique Pan-barrier sheet mainly restricts the upward or normal movement of impact objects while allowing movement tangential to the slope. With the help of gravity, the sheet reduces the upwards jumping of impact objects, and by doing so, guides them back to the ground, where most of the tangential momentum is absorbed. Due to the oblique angle of impact, impact objects are never stopped by the Pan-barrier sheet but merely slide or roll under the sheet. This sliding or rolling further increases impact distance and reduces impact force. Because the normal momentum is small compared to tangential momentum (jumping height is usually only a few feet to over ten feet) and this small momentum is absorbed within extremely large giving distance with the help of sliding, rolling and gravity, the impact force that the Pan-barrier sheet has to absorb is very small compared to the conventional fences, which have to absorb the full load of energy within very short distances, with gravity working against, not for, them. For high mountains or slopes where impact energy is too high for conventional fences and netting the whole mountains is too costly, the Pan-barrier system is a perfect solution.

Maintenance free is a tremendous advantage of the Pan-barrier system. Because impacts are on the ground-facing or underside of the Pan-barrier sheet, impact force only pushes the sheet higher, not lower, and embedding of objects in the Pan-barrier sheet is very rare. In addition, the weight braking system also helps to prevent embedding by forcefully pulling back the tieback cable and the sheet when the weights fall back after impacts. The accumulation of impact objects under the sheet in the wedge-shaped space between the sheet and ground presents no problem at all and is actually beneficial because the accumulated objects can effectively transfer impact energy into the ground if they are hit by later impacts. If the anticipated volume of

debris accumulation is large, reduce the angle between the Pan-barrier sheet and the ground to increase the volume of the wedge-shaped space under the sheet. A small angle also increases the efficiency of the Pan-barrier system during impacts.

Fast installation is a huge advantage of the Pan-barrier system. For leveled ground, the Pan-barrier system only requires a total of two posts and four anchors. The frame cable is laid on the ground first with all the mesh and net sewing and hog ringing work done on the ground to complete the Pan-barrier sheet. Then the sheet is pulled into place through the posts and tensioned by using come-along or the like and further tensioned by attaching weights to the tieback cables. For topographically uneven ground with ridges and valleys, a third post and tieback may be needed at the highest point in between the two end posts to help maintain the height of the Pan-barrier sheet. If the sheet is too high over depressions like valleys, tiebacks without posts may be installed to pull down the top side of the frame cable. The bottom side of the frame cable is held by necessary but minimum number of anchors to follow ground contour.

Material cost for the Pan-barrier system is low because it is almost post-free and does not require high-energy level impact cable nets or ring nets.

Possible modifications to the Pan-barrier system include attaching extra layers of mesh or nets at the toe or bottom of the Pan-barrier sheet where impact objects finally stop. Attaching the top of Pan-barrier sheet to a plethora of upright posts as in conventional impact fences while attaching the bottom of the sheet to ground anchors located away from the posts are possible modifications to the Pan-barrier system. Another possible modification to the Pan-barrier system, although not recommended, is to install a plethora of posts oblique to ground and attach the barrier sheet to both the top and bottom of the oblique posts. Draping a screen of mesh or the like from the top side of the frame cable of the Pan-barrier sheet at the opening of the wedge space is another possible modification to the Pan-barrier system. This draped screen is to slow down objects before impact with the Pan-barrier sheet.